AD-A224 997

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	10 Jul 1990	Final Report/15 Jan 87-14 Jul 90

4. TITLE AND SUBTITLE

Energetic X-Ray Processes in Atoms

5. FUNDING NUMBERS

61102F/2301/A4

(2)

6. AUTHOR(S)

Bernd Crasemann

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Oregon
Dept of Physics & Chemical Physics Institute
Portsmouth, RI 02871

8. PERFORMING ORGANIZATION REPORT NUMBER

AFOSR-TR- 90 0835

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFOSR/NP
Bolling AFB DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AFOSR-87-0026

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Properties of highly stripped ions have been computed relativistically in intermediate coupling with configuration interaction, including quantum electrodynamic effects. Charged-particle ionization cross sections have been calculated, including effect of autoionizing resonances on electron-impact excitation rates. Dielectronic recombination rates have been calculated. An extensive computation of relativistic Auger radial matrix elements has been performed; the results can be used to calculate radiationless transition rates in multiply ionized atoms and are expected to be very useful for the computation of Auger rates in molecules.

14. SUBJECT TERMS

atomic physics, atomic inner-shell processes

15. NUMBER OF PAGES

8

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL SAR

UNIVERSITY OF OREGON

Department of Physics and Chemical Physics Institute

FINAL TECHNICAL REPORT

Energetic X-Ray Processes in Atoms

U. S. Air Force Office of Scientific Research

Grant AFOSR-87-0026

15 January 1987 - 30 June 1990

Program Manager:
Dr. Ralph Kelley, AFOSR/NP
Telephone (202) 767-4904

Principal Investigator:
Dr. Bernd Crasemann
Telephone (503) 346-4754

July 10, 1990

1. Research Summary

With partial support from AFOSR, a broad experimental and theoretical program in research on atomic inner-shell processes has been carried out.

Dynamic correlation phenomena in atoms have been explored experimentally with synchrotron radiation as well as theoretically in terms of resonant scattering theory; special attention has been given to the elucidation of fundamental aspects of rearrangement following ionization in deep inner shells. The relativistic quantum theory of post-collision interaction has been formulated and perfected by inclusion of final-state interactions; critical predictions have been tested through experiments.

Properties of highly stripped ions have been computed relativistically in intermediate coupling with configuration interaction, including quantum electrodynamic effects. Charged-particle ionization cross sections have been calculated, including the effect of autoionizing resonances on electron-impact excitation rates. Dielectronic recombination rates have been calculated. An extensive computation of relativistic Auger radial matrix elements has been performed; the results can be used to calculate radiationless transition rates in multiply ionized atoms and are expected to be very useful for the computation of Auger rates in molecules.

The theory of multiphoton ionization in strong laser fields has been reexamined and tied to basic quantum electrodynamics. By quantizing the field and introducing suitable boundary conditions, a time-independent approach has been developed on the basis of formal scattering theory. The approach has been applied to photodetachment of the negative hydrogen ion, recently explored at LAMF; the theory agrees well with the new data.

2. Publications

Journal Articles

J. Tulkki, G. B. Armen, T. Åberg, B. Crasemann, and M. H. Chen, "Quantum Theory of Post-Collision Interaction in Inner-Shell Photoionization." Z. Physik D 5, 241 (1987).

B. Crasemann, K. R. Karim, and M. H. Chen, "Resource Note: Theoretical Atomic-Electron Binding Energies." At. Data Nucl. Data Tables 36, 355 (1987).

M. H. Chen and B. Crasemann, "Lifetime of the 1s2p3d $^4F_{9/2}$ Metastable State of Li-Like Ions." Phys. Rev. A 35, 4839 (1987).

M. H. Chen and B. Crasemann, "Auger and Radiative Decay Rates of 1s Vacancy States in the Boron Isoelectronic Sequence: Effects of Relativity and Configuration Interaction." Phys. Rev. A 35, 4579 (1987).

M. H. Chen and B. Crasemann, "Dielectronic Satellite Spectra of Li-Like Ions." At. Data Nucl. Data Tables 37, 419 (1987).

K. W. Jones, B. M. Johnson, M. Meron, B. Crasemann, Y. Hahn, V. O. Kostroun, S. T. Manson, and S. M. Younger, "Science with Synchrotron Radiation and a Heavy-Ion Storage Ring." Comm. At. Mol. Phys. 20, 1 (1987).

G. B. Armen, S. L. Sorensen, S. B. Whitfield, G. E. Ice, J. C. Levin, G. S. Brown, and B. Crasemann, "Vanishing Post-Collision Interaction During Photon-Excited Coster-Kronig Decay." Rapid Communications Phys. Rev. A 35, 3966 (1987).

M. H. Chen and B. Crasemann, "K-Shell Auger and Radiative Transitions in the Boron Isoelectronic Sequence." At. Data Nucl. Data Tables 38, 381 (1988).

M. H. Chen and B. Crasemann, "Relative Group Intensities of KMX/KMM and KXY/KMM Auger Transitions in Atoms." J. Phys. B 20, L339 (1987).

G. B. Armen, J. Tulkki, T. Åberg, and B. Crasemann, "Quantum Theory of Post-Collision Interaction in Inner-Shell Photoionization: Final-State Interaction Between Two Continuum Electrons." Phys. Rev. A 36, 5606 (1987).

G. B. Armen, "Angle Dependence of Post-Collision-Interaction Auger Line Shapes. Phys. Rev. A 37, 995 (1988).

S. B. Whitfield, G. B. Armen, R. Carr, J. C. Levin, and B. Crasemann, "Vacancy Multiplication Following Ni L-Shell Photoionization." Phys. Rev. A 37, 419 (1988).

B. Crasemann, "Atomic Inner-Shell Threshold Excitation Phenomena." J. Phys. (Paris) 48, C9-389 (1987).

D.-S. Guo, "Theory of Two-Photon Emission from Atomic Inner Shells." Phys. Rev. A 36, 4267 (1987).

M. H. Chen and B. Crasemann, "Effects of Autoionizing Resonances on Electron Impact Excitation Rates for Be-Like Ions." Phys. Rev. A 37, 2886 (1988).

M. H. Chen and B. Crasemann, "Contributions of Autoionizing Resonances to the Electron Collisional Excitation Rates for Be-Like Ions." At. Data Nucl. Data Tables 41, 59 (1989).

B. Crasemann, "Relativistic Phenomena in Atomic and Chemical Physics: Opportunities for Studies with Synchrotron Radiation." Acta Physica Hungarica 65, 171 (1989).

D.-S. Guo and T. Åberg: "Quantum-Electrodynamical Approach to Multiphoton Ionisation in the High-Intensity Field." J. Phys. A 21, 4577 (1988).

M. H. Chen and B. Crasemann, "Atomic K-, L-, and M-Shell Cross Sections for Ionization by Protons: A Relativistic Hartree-Slater Calculation." At. Data Nucl. Data Tables 41, 257 (1989).

X. Mu and B. Crasemann: "Two-Photon Transitions in Atomic Inner Shells: A Relativistic Self-Consistent-Field Calculation with Applications to Mo, Ag, and Xe." Phys. Rev. A 38, 4585 (1988).

W. Eberhardt, S. Bernstorff, H. W. Jochims, S. B. Whitfield, and B. Crasemann: "Photoelectron Recapture Through Post-Collision Interaction." Rapid Communication, Phys. Rev. A 38, 3808 (1988).

M. H. Chen and B. Crasemann: "Relativistic Calculations of Dielectronic Recombination Rate Coefficients for Be-Like Ions." Phys. Rev. A 38, 5595 (1988).

B. Crasemann: "Photoionization Phenomena Near Threshold." Comments on Atomic and Molecular Physics 22, 163 (1989).

J. C. Woicik, P. Pianetta, S. L. Sorensen, and B. Crasemann: "Photon-Energy Sensitive Si $L_{2,3}$VV Auger Satellite." Phys. Rev. B 39, 6048 (1989).

S. L. Sorensen, R. Carr, S. J. Schaphorst, S. B. Whitfield, and B. Crasemann: "Coster-Kronig Yields in Silver Measured with Synchrotron Radiation." Phys. Rev. A 39, 6241 (1989).

D.-S. Guo, T. Åberg, and B. Crasemann: "Scattering Theory of Multiphoton Ionization in Strong Fields." Phys. Rev. A 40, 4997 (1989).

M. H. Chen and B. Crasemann: "Systematic Trends of the Oscillator Strengths for n=3-2 Electric Dipole Transitions in Oxygenlike Ions." Phys. Rev. A 40, 4330 (1989).

J. Tulkki, T. Åberg, S. B. Whitfield, and B. Crasemann: "Quantum Approach to Photoelectron Recapture in Post-Collision Interaction." Phys. Rev. A 41, 181 (1990).

X. Mu: "Multiphoton Absorption Probabilities in Strong Laser Fields with Application to H^-." Phys. Rev. A (in press).

M. H. Chen, F. P. Larkins, an B. Crasemann: "Auger Radial Matrix Elements for Atomic Numbers $6 \leq Z \leq 92$." At. Data Nuclear Data Tables 45, 1 (1990).

D.-S. Guo and T. Åberg: "Orthogonality of Quantum-Electrodynamical Volkov Solution." J. Phys. A (in press).

X. Mu, J. Ruscheinski, and B. Crasemann: "Multiphoton Detachment Rate of H^- in Strong Laser Fields: Effect of Final-State Interaction." Phys. Rev. A (in press).

D.-S. Guo: "Interaction of an Electron with a Multimode Quantized Radiation Field." Phys. Rev. A (in press).

D.-S. Guo: "Stationary Solutions for an Electron in an Intense Multimode Laser Field." Submitted to Phys. Rev. A.

Items in Conference Proceedings

S. B. Whitfield, G. B. Armen, R. Carr, J. C. Levin, and B. Crasemann, "Vacancy Multiplication Following Ni L-Shell Photoionization." Stanford Synchrotron Radiation Laboratory Users Conference, 22-23 October 1987.

B. Crasemann, "Atomic Inner-Shell Threshold Excitation Phenomena." J. Phys. (Paris) 48, C-9-389 (1988).

G. B. Armen, J. Tulkki, T. Åberg, and B. Crasemann, "Quantum Theory of Post-Collision Interaction in Inner-Shell Photoionization." J. Phys. (Paris) 48, C-9-479 (1988).

B. Crasemann, G. B. Armen, S. L. Sorensen, S. B. Whitfield, G. E. Ice, J. C. Levin, and G. S. Brown, "Post-Collision Interaction in Photon-Excited Coster-Kronig Transitions: Observation of the No-Passing Effect." Bull. Am. Phys. Soc. 32, 1242 (1987).

M. H. Chen and B. Crasemann, "Multiconfiguration Dirac-Fock Calculation of Dielectronic Recombination Coefficients for Be-Like Ions." Bull. Am. Phys. Soc. 32, 1274 (1987).

D.-S. Guo, "A Relativistic Approach to Photon Ionization Theory." Bull. Am. Phys. Soc. 32, 1264 (1987).

T. Åberg, "Origin of X-Ray Fluorescence and Auger Electron Emission." Opening Lecture. Proceedings, Workshop on New Directions in Soft X-Ray Near-Threshold Phenomena, Asilomar, California, 1-4 March 1987. (Unpublished).

T. Åberg, "Theory of Post-Collision Interaction." Invited Lecture. Proceedings, Workshop on New Directions in Soft X-Ray Near-Threshold Phenomena, Asilomar, California, 1-4 March 1987.

X. Mu, B. Crasemann, K. Ilakovac, B. Busic, and V. Horvat, "Two-Photon Transitions in Atomic Inner Shells of Ag: Theory and Experiment." Contributed Paper, Eleventh International Conference on Atomic Physics (ICAP XI), Paris, 4-8 July 1988.

D.-S. Guo and T. Åberg, "Quantum Electrodynamical Approach to Multiphoton Ionization." Contributed Paper, Eleventh International Conference on Atomic Physics (ICAP XI), Paris, 4-8 July 1988.

J. Tulkki, T. Åberg, S. B. Whitfield, and B. Crasemann, "Quantum Approach to Photoelectron Recapture in Post Collision Interaction." Contributed Paper, European Congress on Atomic and Molecular Physics "ECAMP 3," Paris, 1989.

D.-S. Guo, T. Åberg, and B. Crasemann, "Scattering Theory of Multiphoton Ionization in Strong Fields." Contributed Paper, Sixteenth International Conference on the Physics of Electronic and Atomic Collisions, New York, 26 July - 1 August 1989.

M. H. Chen and B. Crasemann, "Dielectronic Recombination and Resonance Excitation Rate Coefficients for Li-Like Ions." Contributed Paper, Sixteenth International Conference on the Physics of Electronic and Atomic Collisions, New York, 26 July - 1 August 1989.

D.-S. Guo and B. Crasemann, "Multimode QED Approach to Multiphoton Ionization in a Single-Mode Laser Field." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

M. H. Chen and B. Crasemann, "Trends of the Energy Levels and Oscillator Strengths for n=3-2 Electric Dipole Transitions of the Oxygen Isoelectronic Sequence." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

X. Mu and B. Crasemann, "Gauge Transformation in Nonrelativistic Quantum Mechanics and Different Forms of the Photon-Electron Interaction." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

M. H. Chen and B. Crasemann, "Dielectronic Recombination and Resonance Excitation Rate Coefficients for Li-Like Ions." Contributed Paper, Sixteenth International Conference on the Physics of Electronic and Atomic Collisions, New York, 26 July - 1 August 1989.

D.-S. Guo, T. Åberg, and B. Crasemann, "Scattering Theory of Multiphoton Ionization in Strong Fields." Contributed Paper, Sixteenth International Conference on the Physics of Electronic and Atomic Collisions, New York, 26 July - 1 August 1989.

D.-S. Guo, T. Åberg, and B. Crasemann, "Final State of Multiphoton Ionization in Strong Fields." Contributed Paper, Conference on Super-Intense Laser-Atom Physics, Rochester, New York, 28-30 June 1989.

X. Mu, "Multiphoton Absorption Rates in Strong Laser Fields with Application to H^-." Abstract of invited paper presented at the Second International Meeting on the Physics of H^-, Albuquerque, New Mexico, November 1989 (unpublished).

M. H. Chen and B. Crasemann, "Autoionizing Resonances in Electron-Impact Excitation of Argonlike Ions." Contributed Paper, Annual Meeting, APS Division of Atomic, Molecular, and Optical Physics, Monterey, 21-23 May 1990. Bull. Am. Phys. Soc. 35, 1172 (1990).

A. Mäntykenttä, H. Aksela, and S. Aksela, "Electron Correlation in the 4d Hole State of Ba Studied by Using Auger Spectroscopy." Contributed Paper, Annual Meeting, APS Division of Atomic, Molecular, and Optical Physics, Monterey, 21-23 May 1990. Bull. Am. Phys. Soc. 35, 1192 (1990).

A. Kodre, S. J. Schaphorst, J. Ruscheinski, Y. Azuma, G. S. Brown, and M. H. Chen, "Double Inner-Shell Photoexcitation of Krypton and Xenon: Observation of Breit-Coulomb Splitting." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

A. Mäntykenttä, B. Crasemann, S. L. Sorensen, and M. H. Chen, "Width of the Xe [3s] Level." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

D. L. Wark, R. Bartlett, T. J. Bowles, R. G. H. Robertson, D. Sivia, W. Trela, J. F. Wilkerson, G. S. Brown, S. L. Sorensen, S. Schaphorst, B. Crasemann, D. A. Knapp, J. Henderson, J. Tulkki, and T. Åberg, "Electron Satellite Spectrum in Photoionization and in Internal Conversion of the Krypton K-Shell." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

X. Mu, "Multiphoton Absorption Rates in Strong Radiation Fields with Application to H^-." Contributed Paper, ICOMP V Fifth International Conference on Multiphoton Processes, Paris, 1990.

J. Tulkki, T. Åberg, S. Schaphorst, and B. Crasemann, "Shake Theory Revised." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

3. Professional Personnel

Bernd Crasemann, Professor of Physics, Principal Investigator

G. Bradley Armen, Research Associate to May 30, 1987

Dong-Sheng Guo, Research Associate to December 31, 1989

Xingdong Mu, Research Associate

Johannes Ruscheinski, Research Assistant

Stephen J. Schaphorst, Research Assistant

Stacey L. Sorensen, Research Assistant to March 15, 1989

Scott B. Whitfield, Research Assistant to June 30, 1989

Mei Chi Chen, Computer Programmer at NASA-ARC (half-time, to December 31, 1989).

Off-campus collaborators:

Teijo Åberg, Helsinki University of Technology

George S. Brown, Stanford Synchrotron Radiation Laboratory

Mau Hsiung Chen, Lawrence Livermore National Labotory

4. Advanced Degrees Awarded

Stacey L. Sorensen, Ph.D., 1989. Thesis: "Atomic Electron Spectrometry with Synchrotron Radiation."

Scott B. Whitfield, Ph.D., 1989. Thesis: "Dynamics of Atomic Photoionization: Studies with Synchrotron Radiation."